

## ABSTRACT

An improved induction tool for formation resistivity evaluations. The tool provides electromagnetic transmitters and sensors suitable for transmitting and receiving magnetic fields in radial directions that are orthogonal to the tool's longitudinal axis with minimal susceptibility to errors associated with parasitic eddy currents induced in the metal components surrounding the transmitter and receiver coils. The present invention provides increased effective tool surface impedance by increasing self-inductance of the paths in which induced eddy currents flow on the surface of the multi-component induction instruments. The tool enables downhole tool designers to build more effective and better-protected radial induction arrays for existing and future downhole instruments operating in the frequency and/or time domains. In this case the array measurement results contain information primarily about the formation's vertical resistivity. The tool makes it possible to combine radial arrays with coaxial arrays that conventionally measure horizontal formation resistivity. This combination enables obtaining a full resistivity tensor to evaluate formation resistivity anisotropy. The tool provides a composite non-conductive housing to reduce or even avoid the effects of parasitic eddy currents flowing on the tool surface. The tool provides a non-magnetic housing that is conductive which reduces the effects of conductive materials near coils and, primarily, the receiver. The tool provides a non-conductive coating is placed over the housing to prevent high frequency eddy currents from leaking from the housing in the conductive mud of the adjacent wellbore and returning to the housing.

The tool method uses measurements for geo-steering applications in vertical, horizontal and deviated well bores. Measurements are taken of time domain response into frequency domain and select a spectrum of interest. The tool provides a tuned, broadband or retunable coil and a tuned, broadband or retunable source. The tool also provides a multi-layer flexible circuit

board containing at least one of a coil, a selectable shield, a magnetic layer and tunable components. The tool also enables dual compensated measurement of array to improve signal to noise ratio and measurement stability and to improve signal content with reservoir, geological and geophysical information. The tool utilizes methods for application for geo-steering, drilling assistance and decisions. The tool provides a transverse magnetic path and in general any magnetic path combination which occurs in a transverse plane perpendicular to the tool longitudinal axis. The tool method utilizes multiple frequency sequential or simultaneous measurements. The tool method utilizes measurements of an array combined with gyro, accelerometer, magnetometer and inclinometer data at same time.

10 Various transmitter receiver combinations are provided to select sensitivity to a desired reservoir formation properties, for example, different orientations xy, xz, yz, 20-40, 20-90, and combinations, such as, Symmetric – symmetric; Asymmetric – symmetric; and Asymmetric – asymmetric. Measurements made with a multi-component logging instrument when used in a substantially horizontal, vertical or deviated borehole in earth formations are diagnostic of the

15 direction of resistive beds relative to the position of the borehole.